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E7.6-10180
CR-146379

LAND USE CHANGE DETECTION WITH LANDSAT-2 DATA FOR MONITORING AND PREDICTING REGIONAL WATER QUALITY DEGRADATION

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(E76-10180) LAND USE CHANGE DETECTION WITH LANDSAT-2 DATA FOR MONITORING AND PREDICTING REGIONAL WATER QUALITY DEGRADATION Quarterly Progress Report, 28 Oct. 1975 - 27 Jan. 1976 (Arkansas Univ.) 11 p HC $3.50 G3/43

N76-18601

Unclas
00180

February 1976
Quarterly Progress Report 28 October 1975 - 27 January 1976

23710

Prepared for

GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland 20771

| 1. Report No. | 2. Government Accession No. | 3. Recipient's Catalog No. |
|---|---|---|
| 4. Title and Subtitle LAND USE CHANGE DETECTION WITH LANDSAT-2 DATA FOR MONITORING AND PREDICTING REGIONAL WATER QUALITY DEGRADATION | | 5. Report Date February 1976 |
| | | 6. Performing Organization Code |
| 7. Author(s) H. C. MacDonald and K. F. Steele | | 8. Performing Organization Report No. |
| 9. Performing Organization Name and Address Geology Department University of Arkansas Fayetteville, Arkansas 72701 | | 10. Work Unit No. |
| | | 11. Contract or Grant No. NAS 5-20810 |
| | | 13. Type of Report and Period Covered Quarterly Progress Report 28 October 1975-27 January 1976 |
| 12. Sponsoring Agency Name and Address Edmund Szajna, Tech. Officer Goddard Space Flight Center Greenbelt, Maryland 20771 | | 14. Sponsoring Agency Code |
| 15. Supplementary Notes | | |

16. Abstract

The overall objective of this research investigation is to compare LANDSAT 1 and 2 imagery for land use change detection which may be correlative with variations in water quality.

Analysis of historical water quality has revealed that while point-source pollution can be generally detected using the water quality sampling data collected by both State and Federal Agencies, non-point source contamination attributable to changing land use is usually completely masked. During the past quarterly period, data analysis would suggest that storm event water quality sampling is far more indicative of the actual influence of land use than information collected during scheduled periods. Specific sites with diverse land use have been selected for the collection of storm event data. In addition we are developing a computer program to analyze, model, and predict water quality under varying conditions, including land use and storm event data.

| 17. Key Words (Selected by Author(s)) | | 18. Distribution Statement | |
|---|---|---|---|
| Arkansas, Change Detection, Land Use, Pollution Monitoring, Water Quality | | | |
| 19. Security Classif. (of this report) | 20. Security Classif. (of this page) | 21. No. of Pages | 22. Price* |
| U | U | 9. | |

*For sale by the National Technical Information Service, Springfield, Virginia 22151.

ABSTRACT

The quality of surface waters can be influenced by many factors; however, land usage now appears to be the dominating factor causing the change in water quality of most streams and rivers in the United States. The extent to which land use change detection with LANDSAT 1 and 2 data can be used for monitoring and predicting regional water quality degradation is the fundamental question to be answered by this investigation. There are two obvious approaches that can be used in evaluating LANDSAT applicability; first, LANDSAT 1 and 2 imagery could be compared for change detection, then areas of change examined for water quality trends; and second, one might observe changes in historical water quality records and then determine if any land use changes have occurred. During the initial phases of this research investigation we have used both approaches.

LANDSAT 1 and 2 imagery analyses have revealed significant changes in land use in the forested areas of Arkansas (as reported in our last quarterly report); however, historical water quality data coincident with these same areas are not available. Based on water quality data analysis for the entire State of Arkansas, it has become apparent that most samples contained in historical records do not reveal the influence of changing land use because they are normally collected at times of low flow. Based on this LANDSAT investigation, we now believe that water quality collected during storm events would be more indicative of changing land use.

We are now monitoring and sampling several control and test streams during times of low flow, and during times of very high flow

(storm events). The sites reflect variations in land use. In addition, we are continuing the development of a computer program which will analyze varying water quality parameters as well as land use, precipitation and stream flow.

## Introduction

In our attempt to determine the feasibility of using LANDSAT land use change detection data for predicting and monitoring regional water quality, it was necessary to analyze historical water quality records for significant changes. Arkansas water quality data which had been collected by various State and Federal agencies for over 40 years, have been compiled, published, and stored in a data retrieval system by the Arkansas Department of Pollution Control and Ecology, and by the USGS (in cooperation with the Arkansas Geological Commission). Similar to many states, Arkansas water quality data are stored on magnetic disk in the IBM 370 computer system of Optimum Systems Incorporated of Bethesda, Maryland. Prior to our LANDSAT investigation, minimal effort had been expended to analyze these data in an attempt to define long term trends, seasonal variation, or water quality characteristics of data collection points. In our last quarterly report we indicated that although water grab samples are taken on a regular basis at over 200 sites in the State, the great majority of samples are taken biweekly, or at best, every two or three months. While it has been possible to detect obvious stream pollution using these data, inconsistency in sampling and data availability have caused data analysis problems.

Areas of obvious land use change (mostly forest clearcutting) detected by comparing LANDSAT 1 and 2 imagery often do not coincide with any of the sampling stations within the State's network, and consequently historical data are lacking. Even where adequate water quality data are available, it is becoming obvious that samples have been collected during the time period which <u>does not</u> reflect the true relationship between

water quality and land use. For example, when flow information is analyzed with water quality records, much of the collecting is accomplished during low flow or base flow conditions. While point-source pollution (sewage effluent, etc.) may be obvious during low flow, most non-point-source contamination (mostly from surface runoff), attributable to changing land use, will not be reflected in the water quality. More specifically, during base flow conditions, we are seeing mostly groundwater in the streams, the quality of which is controlled primarily by the kind of rocks and soil through which the water moves. The water quality of surface runoff (which will be influenced by landuse) then, will have maximum influence on a stream's water quality during storm events, and not during times of base flow.

In an attempt to accomplish the objectives of our LANDSAT investigation, we have reoriented our objectives to include two additional approach phases. First, we have selected several test sites to obtain storm event data during the approaching winter months of 1975, and spring and early summer months of 1976. These sampling sites include areas of contrasting land use, but having similar geologic and geomorphic characteristics. The second phase meshes nicely with the first just mentioned, i.e. in an attempt to make use of the historical water quality data, we are attempting to develop a computer program to analyze, model, and predict water quality under varying conditions, including land use. In contrast to our previous data analyses, event data will be an integral part of this computer model.

Problems

The reorientation of our investigation procedures (described in

the objectives) may necessitate requesting a one month, no-cost extension of our program. The additional one-month period would allow us to collect and analyze storm event data during the early summer months of 1976. We plan to review our proposed sampling schedule after we have collected several sets of storm event data this spring.

## Accomplishments

Storm Event Data Collection. Collection sites were selected for diversity in land use. Two generalized areas were defined on LANDSAT imagery and topographic maps; 1) an area dominated by urbanization, and 2) an area characterized by agricultural land use. Within each area a control stream was selected where minimal land use was in evidence. The control streams will provide "background" water quality data, which can be compared with the "test" stream where land use changes are obvious. During at least one of the storm event collection periods and at one of our control and test sites, the Arkansas Department of Pollution Control and Ecology will collect and analyze water quality data.

In Northwest Arkansas, most streams with even limited access and extreme slope have been developed to some extent, however, the control stream for the agricultural land use test stream is located in the Ozark National Forest and represents a near pristine stream having only limited access. The probability of locating a comparable stream on private land would be extremely slight.

The control and test streams need to be relatively close to enable simultaneous sampling during periods of high flow. Thus, one problem resulted in locating a test stream close to the control that could be detected on LANDSAT imagery; however once selected, flow characteristics

were monitored to assure adequate flow during periods of low flow.

Criteria for Selecting Sampling Sites

1. The control and test watersheds must be detectable on LANDSAT imagery.
2. The control stream must be as near pristine conditions as possible.
3. The control and test watersheds must be reasonably close to allow simultaneous sampling.
4. Both control and test streams must be easily accessible.
5. The test stream was restricted in size allowing a water quality change to be related to land use instead of a direct pollution source.
6. The control and test streams must have sustained flow to allow for low flow sampling.
7. Both control and test watersheds must be similar in geology, size and relief.

All streams will be sampled at least three times during normal flow and twice during high flow conditions. Samples will be collected simultaneously on all three streams during both high and low flow sampling periods. To obtain results for a valid comparison, at least two high flow samples will be collected. The frequency in sampling high flow conditions will depend on the occurrence and extent of precipitation.

One sample per stream will be collected during low flow conditions. Due to the flushing effect, at least three different samples will be collected during a particular storm event. The amount of samples needed during high flow conditions will depend upon the length and severity of the storm.

Water Quality Parameters to be Measured

| | |
|---|---|
| Dissolved Oxygen | ppm |
| Temperature | $^{o}C$ |
| Turbidity | (FTU) |
| pH | |
| Conductivity | ($\mu$ mhos) |
| Alkalinity | mg/l |
| Dissolved Solids | mg/l |
| Suspended Solids | mg/l |
| Settable Solids | mg/l |
| Sulfate | mg/l |
| Chlorides | mg/l |
| Nitrogen: | |
| Ammonia Nitrogen | mg/l |
| Nitrate Nitrogen | mg/l |
| Nitrite Nitrogen | mg/l |
| Phosphate: | |
| Ortho Phosphate | mg/l |
| Total, Inorganic & Meta Phosphate | mg/l |
| Organic & Total Phosphate | mg/l |
| Fecal Coliform Bacteria | #/100ml |

(parameters determined by AA)

| | | | |
|---|---|---|---|
| Calcium | ppm | Potassium | ppm |
| Magnesium | " | Arsenic | " |
| Sodium | " | | |
| Iron | " | | |
| Manganese | " | | |

Computer Modeling

With all factors being considered, every water quality station, and more specifically, every point on the stream, should have a set of characteristic curves that must be constant for that point.

Water quality data from the following stations have been analyzed: Lock & Dam # 1 on the White River, Corning, St. Francis, McDougal, Pocahontas, Dalton, Mammoth Spring, Salem, Eureka Springs, Berryville, Glenwood, and Doddridge in Arkansas; and Thayer in Missouri. These particular water quality stations appear to have the most complete history of sampling, as well as stream flow data that may be reflective of storm events. Water quality parameters showing the most consistent and definitive curves are turbidity, total hardness, BOD, total residue, total coliform, and some trace metals. Several parameters have shown no correlation with variations in streamflow, temperature, or rainfall, with correlations of less than 10 percent. However, data reduction has resulted in up to 98 percent correlation in other parameters.

Quantitive differences in definitive curves with the same general shape have been found between several stations. For example, the parameter total hardness has the same characteristic curve at both Corning and St. Francis, Arkansas, but the quantitive values are quite different; with the values at Corning running about 50 percent above those at St. Francis. We would eventually hope to demonstrate that these types of variations are due to varying streamflow mass values from station to station. Areas where definitive curves are found for particular parameters resulting in a high degree of correlation will be contrasted with those areas where curves are not in agreement. These differences are most certainly leading to indications of differing geology from station to station or area to area, and more importantly to differing land use. With our intended data analysis program, when precise determinations are made as to the causes of varying parameter value curves, the computer will be programmed to accept this material

objectively and be ready to predict water quality changes under varying conditions with emphasis on varying land use.

Significant Results None

Publications None

Recommendations None

Funds Expended Latest computer print-out from University dated 12/30/75 - $24,883.00

Data Use

| Value of Data Allowed | Value of Data Ordered | Value of Data Received |
|---|---|---|
| $1,400.00 | $1,076.00 | $1,076.00 |

Aircraft Data None